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FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OHIO  
INCREASING THE SURVIVABILITY OF COMBAT AIRCRAFT, (U)  
FEB 77 A TUMANOV  
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## FOREIGN TECHNOLOGY DIVISION



INCREASING THE SURVIVABILITY  
OF COMBAT AIRCRAFT

By

A. Tumanov



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By: A. Tumanov

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# U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	<b>А а</b>	A, a	Р р	<b>Р р</b>	R, r
Б б	<b>Б б</b>	B, b	С с	<b>С с</b>	S, s
В в	<b>В в</b>	V, v	Т т	<b>Т т</b>	T, t
Г г	<b>Г г</b>	G, g	У у	<b>У у</b>	U, u
Д д	<b>Д д</b>	D, d	Ф ф	<b>Ф ф</b>	F, f
Е е	<b>Е е</b>	Ye, ye; E, e*	Х х	<b>Х х</b>	Kh, kh
Ж ж	<b>Ж ж</b>	Zh, zh	Ц ц	<b>Ц ц</b>	Ts, ts
З з	<b>З з</b>	Z, z	Ч ч	<b>Ч ч</b>	Ch, ch
И и	<b>И и</b>	I, i	Ш ш	<b>Ш ш</b>	Sh, sh
Й й	<b>Й й</b>	Y, y	Щ щ	<b>Щ щ</b>	Shch, shch
К к	<b>К к</b>	K, k	Ъ ъ	<b>Ъ ъ</b>	"
Л л	<b>Л л</b>	L, l	Ы ы	<b>Ы ы</b>	Y, y
М м	<b>М м</b>	M, m	Ь ь	<b>Ь ь</b>	'
Н н	<b>Н н</b>	N, n	Э э	<b>Э э</b>	E, e
О о	<b>О о</b>	O, o	Ю ю	<b>Ю ю</b>	Yu, yu
П п	<b>П п</b>	P, p	Я я	<b>Я я</b>	Ya, ya

\*ye initially, after vowels, and after Ъ, Ь; е е here.  
 When written as ё in Russian, transliterate а ё.  
 The use of diacritical marks is preferred, but marks may be omitted when expediency dictates.

## GREEK ALPHABET

Alpha	A α	Nu	N ν
Beta	B β	Xi	Ξ ξ
Gamma	Γ γ	Omicron	Ο ο
Delta	Δ δ	Pi	Π π
Epsilon	Ε ε	Rho	Ρ ρ
Zeta	Ζ ζ	Sigma	Σ σ
Eta	Η η	Tau	Τ τ
Theta	Θ θ	Upsilon	Υ υ
Iota	Ι ι	Phi	Φ φ
Kappa	Κ κ	Chi	Χ χ
Lambda	Λ λ	Psi	Ψ ψ
Mu	Μ μ	Omega	Ω ω

# RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English
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sin	sin
-----	-----

cos	cos
-----	-----

tg	tan
----	-----

ctg	cot
-----	-----

sec	sec
-----	-----

cosec	csc
-------	-----

sh	sinh
----	------

ch	cosh
----	------

th	tanh
----	------

cth	coth
-----	------

sch	sech
-----	------

csch	csch
------	------

arc sin	$\sin^{-1}$
---------	-------------

arc cos	$\cos^{-1}$
---------	-------------

arc tg	$\tan^{-1}$
--------	-------------

arc ctg	$\cot^{-1}$
---------	-------------

arc sec	$\sec^{-1}$
---------	-------------

arc cosec	$\csc^{-1}$
-----------	-------------

arc sh	$\sinh^{-1}$
--------	--------------

arc ch	$\cosh^{-1}$
--------	--------------

arc th	$\tanh^{-1}$
--------	--------------

arc cth	$\coth^{-1}$
---------	--------------

arc sch	$\operatorname{sech}^{-1}$
---------	----------------------------

arc csch	$\operatorname{csch}^{-1}$
----------	----------------------------

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rot	curl
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lg	log
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## GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

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FIRST TYPING LINE

## INCREASING THE SURVIVABILITY OF COMBAT AIRCRAFT

A. Tumanov, General-Major of the Engineering and Technical Staff, Meritorious Scientific and Technical Worker of the RSFSR

### 2. Aircraft Armor<sup>1</sup>

Many glorious pages were added to the annals of the Great Patriotic War by our IL-2 attack aircraft pilots. The engine, cockpit, radiator and other of the most vital parts of these aircraft were clad in steel armor. Other countries had neither equal nor even similar aircraft: they aroused fear in the enemy, envy in the allies and admiration in the Soviet servicemen.

"Work on developing armor protection," recalls General Designer of aircraft equipment S. Il'yushin, "contributed to the creation of this aircraft."

One of the most important missions of the All-Union Scientific Research Institute of Aviation Materials [VIAM] during the prewar years, and especially during the menacing years of the war, was to create aviation armor.

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<sup>1</sup>Cont'd. See No. 1, 1968 for beginning.

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We have known about armor for a long time. But it was more than thirty years after the flights of the first aircraft before armored parts appeared in aviation. And this is understandable. It was simpler to clad the thousand-ton hulks of ships in armor.

It was only possible to armor aircraft after a new type of armor was created. This was a lighter form of armor which was considerably more bullet-resistant than that for tanks and ships.

This difficult, critical problem was successfully solved at the beginning of the 'thirties by VIAM scientists Sergey Timofeyevich Kishkin (now an Academician) and Nikolay Mitrofanovich Sklyarov (today Meritorious Scientific and Technical Worker of the RSFSR, Doctor of Technical Sciences, Professor). Conducting extensive experiments, they developed the theory of the interaction of armor with bullets and shells of aircraft weapons and substantiated the theory of the activity of armor. It is well known that for dozens of years the ship and tank armor industry had been following A. F. Ioffe's accurate characterization, the "inverse gun" theory.

The shell acquires speed of up to 1000 m/s in the gun barrel. When it hits ship or tank armor, the shell is embedded into it and moves with negative acceleration until it stops. Virtually all of its kinetic energy is transformed into the plastic flow of the armor. The ratio of the paths of the shell in the armor and in the barrel is determined by that of the pressure in the barrel and the resistance of the armor metal. 7.62 and 12.7 caliber bullets went up to 15-35 mm into ship armor before stopping. This meant that a square meter of armor weighed from 120 to 280 kg. Of course, this armor was

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completely unacceptable for aircraft. S. Kishkin and N. Sklyarov's idea was to cause the kinetic energy of the bullet to be expended on its own destruction, not on deforming the armor. This theory is based on a very simple concept. Although the armor-piercing core of an aircraft bullet or shell is made from extremely strong steel, under certain conditions it can be destroyed easily, even by very weak materials.

For example, it suffices to place an ordinary pencil in the path of a bullet to cause it to acquire a rotational moment relative to its axis when it hits the soft (linden) wood at a high speed. As a result, the armor-piercing core hits the armor flatwise, not with its sharp conical (ogival) head section. Under these conditions, only 5 mm, not 15 mm, of armor is needed to completely stop the bullet or shell. Or, for example, when piercing a thin three-millimeter sheet of high-strength steel, a puncture forms whose asymmetrical shape generates a lateral force which breaks the core up into several pieces.

We could describe many more similar cases when it suffices to have thin armor weighing 15-30% of that of armor operating by the "inverse gun" theory in order to destroy the armor-piercing core.

Several armor protection systems were developed on the basis of experimental and theoretical studies. Three of them were used successfully on attackers: heterogeneous armor, screening armor systems and high-strength armor. In the very first microseconds after the armor-piercing core hit the armor it was smashed to pieces on the hard heterogeneous armor surface. The construction of the screening armor system is curious. It consists of two different plates. When it encountered the first plate, the shell changed direction. Then it hit into the

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second plate, made of high-strength, but rather plastic armor, at a certain angle. A bending moment which cracked the core was created. The plasticity of the armor made it possible for its deformation to prolong the time of the impact until it could change the speed of the fragments by their direction (ricochet).

We should emphasize that the screening armor system successfully protected the IL-10 bomber from 20-mm shells. It is more than 40% lighter than ordinary armor. Subsequently this system was used with equal success on other aircraft.

The difficulties in creating a completely-armored Il'yushin attack aircraft were not exhausted by the development of super-high-strength armor.

There is yet another serious obstacle related to the specific design of the airframe of the aircraft. The modern aircraft is no longer the "flying bookcase" of World War I, but must be very streamlined. Of course, it can be made of ordinary materials and be lined on the inside with armor plates. But in order to avoid losing internal space, even in this case it would be necessary to make the armored components with double curvature to make them follow the outline of the aerodynamic contours of the skin. A double weight expenditure would be obtained - on constructing the airframe, the armor and its reinforcement.

The designer chose to incorporate the armor into the structure of the airframe. What did this mean? This meant that it was necessary to make the skin of the aircraft out of superhigh-strength armor steel with strength 5 times that of duraluminum, rather than of plastic duraluminum (or, as was often the case in those days, of wood veneer, aircraft fabric, and other such easily-shaped materials).

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This was not an easy task. For it was impossible to machine high-strength steel. Furthermore, it warps greatly after it is hardened. This made it impossible to use rolled sheet steel in the hardened state in the automobile industry and other branches of machine building.

Here it was necessary to create large (up to 3 meters) parts with the most complex three-dimensional contours out of 4-6 mm sheets with high enough precision that after installation they resulted in one common surface without the joints overlapping even 1 mm.

It became necessary to create steel that was not only high-strength, but which could assume and precisely retain a given shape after hardening. And this steel was created. The technology for its isothermal hardening simultaneously to forging (with a specific, strictly-controlled forging hold time) was developed.

In 1942 comrades S. T. Kishkin and N. M. Sklyarov were awarded the State Prize for the creation of this steel (AB-1).

Subsequently, in order to decrease the content of scarce elements in armor AB-1 (a problem which became especially critical in view of the sudden increase in the production of IL's in 1942-1944), AB-2 armor was developed without lowering the specifications for bullet-resistance and technological effectiveness. There was half the nickel and one-third the molybdenum in AB-2 as in AB-1. Then an even more economical armor was created - AB-3.

This success was made possible by large-scale research and experiments on solving problems of alloying and hardening steel

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during quenching conducted by a group of Soviet scientists under the leadership of S. Kishkin.

He provided the initiative for developing methods of carbide and intermetallide analyses, as well. These methods made it possible to find out new facts, previously unknown to science, about the processes of quenching and tempering steel; the mechanism of the effect of molybdenum, silicon, nickel and a number of other elements on the structure and properties of steel was explained; the peculiarities of diffusion processes and their significance during plastic flow were explained; etc.

The successful solution of this problem was facilitated by the close interaction of the scientists from the institute and industrial specialists.

Plant director, Candidate of Technical Sciences, Engineer-Colonel V. Zasl'skiy, who organized the assembly-line method of producing completely-armored fuselages, a large structure made of three-dimensional parts, displayed a great deal of initiative, creativity and steadfastness. The fuselage was broken down into a number of basic assemblies. Each of them was added to the unit in turn, providing the extensive use of unit and part assembly, continuity, and the shortest possible time taken for the operation.

The use of the loft former method made it possible to create the industrial equipment for connecting parts and units, observing the geometric shape of the article as a whole when joining them.

Two assembly lines were constructed for manufacturing armored fuselages: one was continuous with a controlled rhythm, and

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the other - with a free rhythm and incomplete synchronization of the operations in the aggregate assembly sections.

Considerable attention was given to the extrusion equipment, forming facilities, and the myriad of forging and quenching devices which made it possible to obtain precise contours.

As a result of the united efforts of scientists, metallurgists, technologists and industrial workers, the mass assembly-line production of 46 armored fuselages of attack aircraft was provided per day according to a strict daily schedule. The aircraft industry sent more than 40 thousand high-quality armored IL's to the front. This was the heroism of the laborers in the rear, who contributed to our victory in the Great Patriotic War.

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